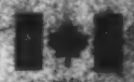
ISSN 0317-0136



National Research Council Canada
Conseil national de recherches Canada

ENVIRONMENTAL ASPECTS OF *SALMONELLA* IN HUMANS

NRCC No. 27537

88-04441/

NATIONAL RESEARCH COUNCIL OF CANADA
NRCC ASSOCIATE COMMITTEE ON SCIENTIFIC CRITERIA FOR
ENVIRONMENTAL QUALITY

ENVIRONMENTAL ASPECTS OF *SALMONELLA* IN HUMANS

by

D.M. McLean
Medical Microbiology, University of British Columbia
Vancouver, B.C. V6T 1W5

Publication No. NRCC 27537

Crown Copyright Reserved
1987

Available through prepaid order only from:

Publications, NRCC/CNRC
Ottawa, Canada K1A 0R6

Price: $5.00

MANDATE OF THE ASSOCIATE COMMITTEE ON SCIENTIFIC CRITERIA FOR ENVIRONMENTAL QUALITY

The Associate Committee on Scientific Criteria for Environmental Quality was established by the National Research Council of Canada in response to a mandate provided by the Federal Government to develop scientific guidelines for defining the quality of the environment. The concern of the NRCC Associate Committee is strictly with scientific criteria. Pollution standards and objectives are the responsibility of the regulatory authorities and are set for the purpose of pollution control. These may be based on scientific criteria as a starting point but they also take into account the optimal socioeconomic impact of proposed measures as well as the state of existing technology.

The Associate Committee's program includes the evaluation of available information on the probability of effects of contaminants on receptors together with the related fundamental principles and scientific knowledge. In this work particular attention is directed to receptors and contaminants (and their interactions) important to Canada. This Canadian approach is necessary because evaluations made in other countries or regions will not always be applicable to the particular circumstances prevailing in Canada.

Members of the Associate Committee, its Subcommittees and Expert Panels, serve voluntarily and are selected for their individual competence and relevant experience with due consideration for a balance among all sectors in Canada. Responsibility for the quality of study documents rests with the Associate Committee. Each report is carefully reviewed according to a multistage procedure established and monitored by the National Research Council of Canada in order to preserve objectivity in presentation of the scientific knowledge. Publication and distribution of the report are undertaken only after completion of this review process.

Comments on Associate Committee documents are welcome and will be carefully reviewed by the Expert Panels. It is foreseen that these scientific criteria may be revised from time to time, as new knowledge becomes available.

All documents published by the Associate Committee are published in both French and English.

ACKNOWLEDGEMENTS

The Associate Committee appreciates most gratefully the generous provision of nationwide statistical data on salmonellosis of human and veterinary relevance by the following:

Dr. Ewen D. Todd
Food Directorate
Bureau of Microbiological Hazards
Health Protection Branch
Health and Welfare Canada
Ottawa, Ontario K1A 0L2

Dr. Claude Lavigne
Chief, Salmonella and Food-Borne Disease
Animal Health Division
Food Production and Inspection Branch
Agriculture Canada
Ottawa, Ontario K1A 0Y9

EXECUTIVE SUMMARY

Outbreaks of gastroenteritis due to non-typhoid serovars of Salmonella sp. involved 6781 to 11 181 human residents throughout Canada each year between 1978 and 1985, with a nationwide mean annual attack rate of 34 per 100 000 population. Of the 404 reported episodes of food-borne salmonellosis occurring between 1973 and 1982, 321 episodes involving 10 004 persons were attributed to infection with 40 single Salmonella serovars. The seven most common serovars associated with 10 or more episodes were S. typhimurium (127, involving 3843 subjects), S. enteritidis (31), S. infantis (20), S. heidelberg (16), S. saint-paul (16), S. muenster (11) and S. thompson (10). Turkey was the commonest food vehicle involved with 102 episodes arising from 25 serovars, and chicken was implicated in 63 episodes involving 14 serovars. The commonest serovar isolated from all food vehicles was S. typnimurium. Restaurants and/or bakeries were both the commonest purveyors and the commonest sites of preparation of Salmonella-infected foodstuffs. Annual Salmonella infection rates of 52 to 61% were found in poultry marketed fresh and 15% in animal feedstocks. Direct costs of Salmonella outbreaks ranged from $23 523 at a bakery to $61 528 at an institution for mentally retarded children. Recommendations advocate repeated in-service training of food handlers in correct food preparation and hygienic practices and reinstitution of national reporting of antibiotic sensitivities of human and veterinary Salmonella isolates.

TABLE OF CONTENTS

		PAGE
ACKNOWLEDGEMENTS		iv
EXECUTIVE SUMMARY		v
LIST OF TABLES		ix
1.0	INTRODUCTION	1
2.0	OBJECTIVES	3
3.0	DEFINITIONS	5
3.1	Laboratory techniques	6
4.0	*SALMONELLA* AND HUMAN ILLNESS	7
4.1	Clinical manifestations	7
4.2	Antibiotic resistance	7
4.3	Epidemiology	8
5.0	ENVIRONMENTAL SOURCES OF *SALMONELLA*	11
5.1	Food-borne episodes of salmonellosis	11
5.2	*Salmonella* infections in foodstuffs before distribution commercially	15
5.3	Examples of food-borne salmonellosis episodes	20
5.3.1	*Salmonella enteritidis* transmission by cakes	20
5.3.2	*Salmonella typhimurium* transmission by dessert	20
5.3.3	*Salmonella berta* transmission by raw goat milk	20
5.4	Salmonellosis from other environmental sources	20
5.4.1	Gastroenteritis at a daycare	20
5.4.2	*Salmonella typhimurium* transmission by garter snake	21
5.4.3	*Salmonella poona* transmission by turtles	21
6.0	COSTS OF SALMONELLOSIS EPISODES	23
6.1	Direct costs	23
6.1.1	*Salmonella typhimurium* at an institution for mentally retarded children	23
6.1.2	*Salmonella infantis* and *S. java* in a family	23
6.1.3	*Salmonella bareilly* spread from a bakery	24

TABLE OF CONTENTS (CONT'D)

		PAGE
7.0	SCIENTIFIC CRITERIA	25
7.1	Salmonellosis associated with foodstuffs and their method of preparation and distribution	25
7.2	*Salmonella* attack rates by province	26
8.0	PREAMBLE TO RECOMMENDATIONS	29
8.1	Proper handling of foodstuffs	29
8.2	Antibiotic sensitivities	29
9.0	RECOMMENDATIONS	31
9.1	Proper handling of foodstuffs	31
9.2	Antibiotic sensitivities	31
REFERENCES		33

LIST OF TABLES

TABLE		PAGE
4-1	Reported cases of human Salmonella sp. infections in Canada 1978-1985.	9
5-1	404 food-borne Salmonella episodes in Canada 1973-1982.	12
5-2	Summary of association between seven Salmonella serovars each causing 10 or more episodes and location of occurrence of infection in implicated foodstuff 1973-1982.	13
5-3	Salmonellosis in human residents of Canada during 1984.	16
5-4	Salmonella isolation rates from meats, eggs, milk, animal feeds in Canada 1980-1985.	17
5-5	Salmonella isolations from various categories of animal feed.	18
5-6	Salmonella serovars isolated from milk powder plants 1980-1984.	19

1.0 INTRODUCTION

Despite generally good sanitation practices throughout Canada during most of the twentieth century, outbreaks of gastroenteritis due to non-typhoid serovars of Salmonella sp. involved 6781 to 11 181 human residents of all provinces and territories of Canada each year between 1978 and 1985 (Health and Welfare Canada 1986). Many outbreaks arise from unsanitary food-handling techniques by volunteers at community social events or by inadequately trained kitchen staff at commercial food-preparation facilities, whilst single cases or small clusters of patients may contract salmonellosis through direct or indirect exposure to infected farm animals or domestic pets

Prevalence of particular Salmonella serovars has changed through succeeding years, except for that of Salmonella typhimurium which has remained high every year. Emergence of serovars with plasmid-mediated multiple antimicrobial resistance during recent years has often been associated with the increased use of animal foodstuffs containing several antibiotics which promote increased meat production per animal.

2.0 OBJECTIVES

The objective of this document is to assemble a quantitative data base relating the number of human cases of salmonellosis per annum of approximately 40 common Salmonella serovars, to the category of location of exposure to the infected environmental source. Costs of health care for infected humans, plus relevant microbiological laboratory investigations of patients and environmental sources of infection, are presented whenever appropriate.

3.0 DEFINITIONS

The genus Salmonella comprises over 2000 serologically distinct bacterial serovars (formerly designated as "species") which are Gram-negative straight rods 0.7-1.5 x 2.0-5.0 µm within the family Enterobacteriaceae (Bergey's Manual of Systematic Bacteriology 1984). Salmonella is usually motile by peritrichous flagella, and is facultatively anaerobic. Colonies are generally 2-4 mm in diameter. Nitrates are reduced to nitrites. Gas is usually produced from glucose. Hydrogen sulfide is usually produced on triple-sugar iron agar; citrate is usually utilized as a sole carbon source; lysine and ornithine decarboxylase reactions are usually positive; Salmonella is indole-negative, and urease-negative. Phenylalanine and tryptophan are not oxidatively deaminated. Sucrose, salicin, inositol and amygdalin are usually not fermented. Lipase and deoxyribonuclease are not produced. Salmonella is pathogenic for humans, causing enteric fevers, gastroenteritis and septicemia; it may also infect many animal species besides humans. Some serovars are strictly host-adapted. The mol% G + C of the DNA is 50-53 (Ch, Tm Bd).

Salmonella typhi, the causative organism of typhoid fever, is an important exception to production of gas from glucose; it never produces gas.

The genus is divided into serovars on the basis of the antigenic composition of the cell wall (somatic, O antigen), flagella (H antigens in phase 1 and phase 2) and capsule (Vi). Each serovar has a particular antigenic formula: one or more numbers for O, letters in lower case for H phase 1, numbers or lower-case letters for H phase 2. Each serovar is designated characteristically after the city or jurisdiction in which the particular serovar was first isolated; for example, S. eastbourne is 1, 9, 12: e, h: 1, 5; S. toronto is 9.46: 1, v: e, n, x; S. vancouver is 16: c: 1, 5. Lysogenization by certain converting bacteriophages may produce changes in the O antigenic formula, and all factors concerned with phage conversion are underlined.

Serovars may be subdivided into several biovars according to their sugar fermentation patterns.

Phagovars are determined by the sensitivity of cultures to a series of bacteriophages at appropriate dilutions - this applies particularly to S. typhimurium and S. typhi with important epidemiological implications.

On the basis of DNA/DNA hybridization experiments, all salmonellae and arizonae comprise one "genus" containing one "species" because all serotypes exhibit greater than 70% relatedness to each other. For convenience during recent years, serovars have been clustered into six subspecies I through VI, superseding an earlier

designation of five subgenera. Subspecies I contains S. typhi plus most of the important human pathogenic non-typhoid salmonellae; subspecies III contains serovars previously designated S. arizonae.

3.1 LABORATORY TECHNIQUES

Methods for detection of Salmonella strains in foodstuffs involve homogenization of the foodstuff in 10 volumes of nutrient broth, pre-enrichment overnight at 35°C, inoculation of enrichment broths (tetrathionate-brilliant green and selenite-cystine at 43 and 35°C, respectively) and incubation overnight. Enrichment cultures are plated on bismuth sulfite and brilliant green agar. Suspect colonies are purified on MacConkey agar and then screened biochemically on triple-sugar iron and lysine iron agar. Isolates are confirmed serologically using polyvalent and single grouping antisera. These methods were developed and described by Health and Welfare Canada (1978a) and they are consistent with the practices of the Association of Official Analytical Chemists (1984). Time for identification of Salmonella has been shortened by 6-hour incubation of media, followed by filtration through hydrophobic grid-membrane filters (HGMF) which are incubated directly on Hektoen enteric agar and selective lysine agar and incubated at 35 and 43°C, respectively, for 24 hours. The HGMF with Salmonella sp. colonies are washed and examined by an enzyme immunoassay procedure directly on the membrane filters (Cerqueira-Campos et al. 1986), and the results can be read with automated equipment.

4.0 SALMONELLA AND HUMAN ILLNESS

4.1 CLINICAL MANIFESTATIONS

Gastroenteritis is the commonest clinical manifestation of infection with Salmonella sp. After an incubation period of 1-4 days, patients suddenly develop 3 to 10 or more watery, loose stools per day, often accompanied by crampy abdominal pain and/or vomiting, sometimes with elevation of the temperature to 38°C or more. The total leukocyte count remains low with a proportionate decrease in polymorphonuclear leukocytes. Untreated, the fever may persist for 2-3 days and diarrheal stools for about one week. If chloramphenicol or ampicillin is prescribed within 2 days after onset of fever and diarrhea, symptoms usually abate within 1 day. Although the complications of non-typhoid Salmonella infections are rare, occasional subjects, particularly infants, may develop arthritis or osteomyelitis following spread of bacteria through the bloodstream.

Typhoid fever, due to infection with S. typhi, is a clinically severe illness which has affected 64 to 103 persons in Canada each year between 1978 and 1984. Although some Canadians contract typhoid fever whilst travelling abroad, indigenous cases continue to appear rarely; in most instances they are traced by contact through water, food or fomites to a typhoid carrier. Symptoms begin with severe headache, high fever, constipation or diarrhea, sometimes accompanied by "rose spots" over the skin. Untreated the fever and headache may persist one week or longer, but they subside promptly within 48 hours after commencement of chloramphenicol therapy, provided that the infecting bacterium is sensitive to this antibiotic. A major outbreak occurred in Vancouver, B.C., during January 1970 among 58 passengers and crew of a cruise liner which arrived recently from the Caribbean. Oral chloramphenicol therapy induced prompt clinical remissions in all these patients. Inadequate flushing of freshwater holding tanks following plumbing repairs appeared to introduce the S. typhi infection into the ship's water supply.

4.2 ANTIBIOTIC RESISTANCE

An emerging problem during the 1970's was the upsurge of strains of typhoid and non-typhoid Salmonella with plasmid-mediated resistance to one or more of the commonly prescribed antibiotics, including chloramphenicol and ampicillin. A high prevalence of antibiotic-resistant Salmonella was found among travellers returning to Canada from Mexico and other Central American countries. Additionally, several previously rare Salmonella serovars were isolated more frequently during the 1970's, from both human and animal sources, and many strains were highly antibiotic-resistant.

4.3 EPIDEMIOLOGY

Throughout Canada between 1 January 1978 and 21 December 1985, Salmonella infections were reported in 66 353 persons (Table 4-1) (Health and Welfare Canada 1986). This represents a mean nationwide annual attack rate of 34 per 100 000. Salmonella was detected in three or more residents of every province and territory during every year of this eight-year period, with a maximum of 4869 Ontario residents involved during 1984, representing an attack rate of 57 per 100 000 as compared with the provincial mean rate of 43 and minimum rate of 27 during 1978. Provincial annual attack rates per 100 000 ranged from 17 in New Brunswick and 22 in Manitoba through 55 in Newfoundland and 92 in Prince Edward Island, with a maximum of 95 in the Northwest Territories. Although peak annual reportings varied from province to province according to local conditions, maximum reportings for Canada of 11 181 cases in 1984 also included maximum incidences for each of the four Atlantic provinces plus Ontario which together comprise almost half the Canadian population.

Table 4-1. Reported cases of human Salmonella sp. infections in Canada 1978-1985.

Jurisdiction Total	1978	1979	1980	1981	1982	1983	1984	1985	Rate*
Canada 66 353	6781	7199	8516	7734	8495	8936	11181	7511	34
Newfoundland 2491	229	144	162	264	205	161	1223	103	55
Prince Edward Island 896	17	69	48	39	92	67	526	38	92
Nova Scotia 943	160	79	146	293	295	368	438	164	29
New Brunswick 957	56	116	164	100	131	86	225	79	17
Quebec 13 026	1186	1903	2021	1824	2177	1561	1484	870	25
Ontario 29 760	2296	2859	3834	3438	3561	3936	4869	4467	43
Manitoba 1778	254	235	219	264	197	227	234	148	22
Saskatchewan 2957	262	231	230	248	456	836	495	199	37
Alberta 5507	854	746	727	404	573	735	736	732	30
British Columbia 6619	908	755	853	811	767	940	919	666	31
Yukon Territory 91	33	20	3	15	9	4	3	4	48
Northwest Territories 328	26	42	109	34	32	15	29	41	95

* Mean annual rate of reported infections per jurisdiction per 100 000 population (1981 census).

5.0 ENVIRONMENTAL SOURCES OF *SALMONELLA*

5.1 FOOD-BORNE EPISODES OF SALMONELLOSIS

Throughout Canada between 1973 and 1982, reports of 404 episodes of food-borne infection with *Salmonella* serovars were compiled by the Bureau of Microbiological Hazards of the Food Directorate, Health Protection Branch, Health and Welfare Canada (Table 5-1). These comprised 321 episodes involving 10 004 persons which were attributed to infection with 40 single *Salmonella* serovars, 51 episodes involving 513 persons in which the causative *Salmonella* serovar was not identified, and 32 episodes involving 1650 persons where more than one serovar was identified. The latter included 17 episodes associated with the same pair of serovars; 11 episodes involved *S. typhimurium* plus one or more serovars. Of the 40 causative serovars identified, the commonest was *S. typhimurium* which was implicated in 127 episodes involving 3843 subjects; other serovars associated with 10 or more episodes were *S. enteritidis* (31), *S. infantis* (20), *S. heidelberg* (16), *S. saint-paul* (16), *S. muenster* (11) and *S. thompson* (10). These are summarized in Table 5-2. Additional serovars within the "top ten" were *S. schwarzengrund* (9 episodes), *S. newport* (8) and *S. montevideo* (7).

Many of the above serovars are encountered repeatedly in other jurisdictions beyond North America as causes of human salmonellosis. For example, in Great Britain during the second quarter of 1986, *S. typhimurium* and *S. enteritidis* principally, and to a lesser extent *S. heidelberg* and *S. newport*, were among the "top ten" *Salmonella* isolates from humans (Public Health Laboratory Service 1986).

Causative salmonellae were isolated from one or more patients in 379 episodes, from the food vehicle in 113, and from a food handler in 88 episodes (Table 5-1). These isolates comprised 40 typed *Salmonella* serovars from 321 episodes involving 10 004 subjects; 51 untyped *Salmonella* strains from 51 episodes affecting 562 persons; and 32 multiples of *Salmonella* serovars from 32 episodes involving 1655 people, including 17 episodes arising from the same pair of serovars and 11 episodes where *S. typhimurium* was one of the infecting serovars.

Turkey was the commonest food vehicle involved, with 102 episodes arising from 25 serovars; chicken was implicated in 63 episodes involving 14 serovars; raw milk induced 35 outbreaks involving 6 serovars; beef and pork each accounted for 28 outbreaks involving 10 and 9 serovars, respectively; eggs caused 24 episodes arising from 10 serovars; fish were implicated in 13 outbreaks comprising 8 serovars; and desserts induced 7 episodes involving 7 serovars.

Among individual serovars isolated from food vehicles, *S. typhimurium* was the commonest isolated from all sources, particularly fresh or inadequately cooked turkeys and chickens, but also beef and

Table 5-1. 404 food-borne Salmonella episodes in Canada 1973-1982.

Salmonella serovar	Episodes	Cases	Salmonella isolations per episode: patient	food vehicle	food handler	Food vehicle: dessert	raw milk	turkey	fish	chicken	egg	beef	pork	Where infection acquired: hospital	shop	camp	restaurant/ bakery	social	farm	home	Where food mishandled: hospital	shop	camp	restaurant/ bakery	catering company	catering voluntary	manufacture	farm	home
agona	5	202	5	2	1			1		1		1		1	1	1		1			1		2			1			
anatum	3	89	3	0	0		2							1					1		1							2	1
arizona	2	22	2	1	0						1			1	1						1				1				
bareilly	3	157	3	2	1	1					1			1						1	1				1		1		
blockley	5	182	5	2	3			1	1					1			3			1	1			2	1				1
brandenburg	2	161	2	0	2	1		1					1					2						1	2				
branderup	3	96	3	1	1			1									1	2						1		2			
bredeney	2	6	2	1	0					1										1									1
cerro	1	17	1	0	1									1						1									
chester	2	4	1	1	0			1						1						1	1								1
eastbourne	3	107	3	3	0	1		1									1			1				1			1		
enteritidis	31	1563	29	4	9	1	2	2	1	3	5	4	4	5	4	1	12	3		4	5	1	1	9	2				4
haardt	4	178	4	0	2			8									3	1						3					
hadar	7	138	7	5	5			3				2		2		1	2	1		1	1		1	2	2				
havana	1	1	1	0	0			1												1									
heidelberg	16	795	12	7	4			8		4				2	1	1	2	7	1	1	2		1	3	1	2	3	1	2	
infantis	20	386	17	8	2	1		1	1	8	3	1	1	5	3		6	1		5	5	3		4	1		1		3	
java	1	5	1	0	0				1											1									1	
kentucky	1	41	1	1	0	1											1								1				
litchfield	2	35	2	0	1			1									2							2					
manhattan	1	28	1	0	1					1				1							1								
manschout	1	1	1	1	0		1													1									1
montevideo	7	191	7	2	2			1	1	2	2			1	1		2	2		1	1			2	1		1		2
muenchen	2	19	2	0	1			1						1				1			1				1				
muenster	11	191	11	7	2		5	1							3		1		6	1				2		3		6	
newport	8	305	8	3	2			3					2	2		1	3	1		1	1		1	5	1				
orion	1	2	1	0	0							1					1							1					
panama	1	20	1	0	0					1							1								1				
paratyphi B	2	59	2	1	0			1					1	1				1			1								1
reading	1	2	1	0	0					1							1							1					
saint-paul	16	264	15	3	1			6	3					1			5	3		4				6	1				4
san-diego	4	248	4	2	1			4									2			1				2	1				1
schwarzengrund	9	267	9	4	3			1	1	2	1	1	2		1		3	2		3		1		3	2				3
seeftenberg	1	21	0	1	0	1											1							1					
tallahasse	1	5	0	0	0												1												
thompson	10	337	10	4	1			5		4				1		1	4	2		2	1		1	3	1	1			2
typhi	1	7	1	0	0							1					1						1						
typhimurium	177	3843	121	29	31		14	27	4	25	6	13	8	12	10	3	39	26	4	28	11	10	2	14	10	11		6	22
urbana	1	24	1	1	0						1							1							1				
weltevreden	2	15	2	0	0							2								2						2			
untyped	51	562	47	7	3		7	9		11	1	2	6	3	9		12	8	5	13	3	1		11	2	4	1	6	7
multiple serovars	32	1655	30	9	8			17		1	3		3	5		2	10	8		5	5	1	1	10	8	2	1		5
TOTALS	[a]404	12 221	[b]379/40	113/27	88/24	7/7	35/6	102/25	13/8	63/14	29/10	28/10	28/9	49/21	34/10	11/8	120/26	73/19	15/5	80/23	45/20	17/6	10/8	111/25	38/20	23/7	14/9	21/5	62/18

[a] 321 episodes comprising 10 008 patients were associated with 40 Salmonella serovars.

51 " " 562 " " " " untyped Salmonella isolate.

32 " " 1655 " " " " multiple Salmonella serovars; 17 episodes with same pair of serovars; 11 episodes included S. typhimurium.

[b] numerator: number of episodes/denominator: number of serovars involved.

Table 5-2. Summary of association between seven Salmonella serovars each causing 10 or more episodes and location of occurrence of infection in implicated foodstuff 1973-1982.

Serovar	Prevalence		Episodes where environmental source identified		
	Episodes	Cases	Foodstuff	Purveyor	Mishandled
typhimurium	127	3843	50/95 (53%) P	39/124 (31%) R-B	34/106 (32%) R-B
enteritidis	31	1563	5/22 (23%) E	12/29 (41%) R-B	9/22 (41%) R-B
infantis	20	396	9/16 (56%) P	6/20 (30%) R-B	5/17 (29%) H
heidelberg	16	795	12/12 (100%)P	7/15 (47%) S	3/15 (20%) R-B
saint-paul	16	264	6/9 (67%) P	5/13 (38%) R-B	6/11 (55%) R-B
muenster	11	191	9/10 (90%) M	6/11 (55%) F	6/11 (55%) H
thompson	10	337	9/9 (100%)P	4/10 (40%) R-B	3/9 (33%) R-B
TOTAL	231	7389	100/173 86P (50%)	79/222 66 R-B (30%)	66/191 55 R-B (29%)

E: egg; F: farm; H: hospital; M: raw milk; P: poultry; R-B: restaurant and/or bakery; S: social function.

pork. Salmonella heidelberg was the commonest non-typhimurium serovar isolated from turkeys, followed by S. saint-paul and S. thompson, and S. infantis, S. heidelberg and S. thompson were detected repeatedly in chickens. However, S. enteritidis was the most common non-typhimurium serovar recovered from eggs, and also from beef and pork. Salmonella muenster was commonly detected in raw milk, especially when it was obtained directly from farms.

Restaurants, including bakeries, were the commonest purveyors of foodstuffs which subsequently induced outbreaks of salmonellosis, with 120 episodes arising from 26 serovars (Table 5-1). Other frequent locations for acquisition of Salmonella infection were homes, with 80 episodes involving 23 serovars; social functions catered voluntarily induced 73 episodes with 19 serovars; and hospitals accounted for 49 episodes involving 21 serovars. Relatively few episodes of salmonellosis were reported from food purchased at retail shops, farms or camps. Salmonella typhimurium was the commonest serovar identified in infections acquired at any location, but other less common serovars were S. enteritidis, S. heidelberg and S. infantis. A noteworthy feature of salmonellosis contracted from farm foods was the high proportion of S. muenster infections, where raw milk was commonly the vehicle of infection. Among non-typhimurium infections acquired through restaurants or bakeries, serovars commonly isolated included S. enteritidis, S. infantis, S. saint-paul, S. schwarzengrund and S. thompson, and these serovars also were implicated frequently in home-acquired salmonellosis. Salmonella heidelberg, S. enteritidis and S. saint-paul were detected frequently in episodes following social functions catered voluntarily.

Restaurants and/or bakeries were the commonest locations at which foodstuffs were mishandled, thus permitting transmission of Salmonella infections, including 111 episodes induced by 25 serovars, including 34 episodes caused by S. typhimurium. Of the non-typhimurium serovars, S. enteritidis, S. infantis, S. saint-paul and S. newport were the most frequent isolates. Hospitals, including homes for the aged, were involved in 45 episodes arising from 20 serovars, most prominent of which were S. typhimurium, S. enteritidis and S. infantis. Catering companies were the site of food mishandling in 38 episodes due to 20 serovars, and volunteer catering groups were implicated in 23 outbreaks arising from 7 serovars, but in both categories S. typhimurium was the only dominant serovar. Food mishandled at home gave rise to 62 episodes involving 18 serovars, most commonly due to S. typhimurium, but other serovars which featured prominently were S. enteritidis, S. infantis, S. schwarzengrund and S. saint-paul.

In summary, S. typhimurium was clearly the dominant serovar associated with episodes of salmonellosis throughout Canada between 1973 and 1982. Other serovars commonly implicated included S. enteritidis, S. infantis, S. heidelberg, S. saint-paul, S. muenster and S. thompson (Table 5-2). This decennial baseline distribution of Salmonella

serovars corresponded well with 15 serovars encountered most commonly in human infections throughout Canada except the Province of Quebec during 1984 (Table 5-3).

5.2 SALMONELLA INFECTIONS IN FOODSTUFFS BEFORE DISTRIBUTION COMMERCIALLY

Routine bacteriological surveillance of a wide range of agricultural products by the Food Production and Inspection Branch of Agriculture Canada before these products were marketed as foodstuffs revealed Salmonella contamination rates of 52% in turkeys, 60% in geese and 61% in chicken broilers (Table 5-4). Chicken broilers were sampled in groups of 500 during each fiscal year between 1980 and 1985; other poultry and red meats were surveyed less frequently. However, infection rates in beef (2.7%) and pork (12%) were substantially lower than in poultry. Effective heat treatment of meat products virtually eliminated Salmonella infection. Processed egg products showed a low (0.2%) infection rate, despite a somewhat higher (1.1%) environmental infection rate. Appreciable infection (2.9%) was found in fluff from chicken hatcheries which indicated exposure of recently hatched chickens to environmental Salmonella.

The major source of Salmonella infection for domestic animals which were marketed as human foodstuffs appeared to be animal feed; this showed an overall 15% annual infection rate between 1980 and 1985 (Table 5-4). Of the 253 Salmonella isolates from 1734 samples, meat and bone meal yielded 114 isolates, premix supplement yielded 50 and fish meal yielded 36 strains (Table 5-5). Thus, the meat-related components of animal feedstocks, which were not heat-treated, continuously introduced Salmonella organisms into the animal food chain. This infection hazard could be eliminated by proper heat sterilization of all animal foodstuffs, as demonstrated.

Surveillance of milk delivered to powder plants between 1980 and 1984 yielded 234 Salmonella isolates within 25 serovars, plus 36 untyped strains (Table 5-6). Serovars occurring most commonly were S. agona (50), S. senftenberg (39), S. tennessee (19), S. anatum (16), S. thompson (15) and S. muenster (9). The seven isolates of S. muenster during 1982, and its infrequent detection in subsequent years, paralleled its isolation from raw milk or cheese during eight episodes of human salmonellosis during 1982 which were attributed to these food vehicles. However, surveillance of dried milk products (Table 5-4) showed consistently low infection rates of 0.2% overall, thus demonstrating the efficacy of heat treatment to remove human bacterial pathogens.

Fish and other seafoods which are imported from tropical and Third World countries are routinely sampled bacteriologically. Salmonella-infected fish products are refused entry into Canada.

Table 5-3. Salmonellosis in human residents of Canada during 1984.

Serovar	Human* + infections 1984	Human isolates 1973-1982
typhimurium	6548	3843
heidelberg	487	795
infantis	391	396
enteritidis	282	1563
hadar	281	138
agona	214	202
saint-paul	202	264
newport	127	305
montevideo	123	191
thompson	112	337
haardt	106	178
schwarzengrund	99	267
branderup	94	96
muenchen	87	19
typhi	78	7

* Data supplied by National Enteric Reference Centre, Laboratory Centre for Disease Control, Health and Welfare Canada.

\+ Includes all provinces except Quebec.

Table 5-4. *Salmonella* isolation rates from meats, eggs, milk, animal feeds in Canada 1980-1985.*

Fiscal year		Chicken broilers	Turkeys	Geese	Beef	Pork	Heated meat products	Animal feed	Processed egg plants		Hatcheries fluff	Dried milk plants	
									Egg product	Environment		Milk product	Environment
1980/81	rate	335/500					0/499		33/704				
	%	67					-		4.7				
1981/82	rate	300/500	33/135				0/560	51/396	97/1121			4/4311	42/4553
	%	60	24				-	13	8.6			0.1	0.9
1982/83	rate	315/500		78/130			0/2080	62/576	55/966	4/138	36/3377	12/4636	25/2935
	%	63		60			-	11	5.7	2.9	1.1	0.3	0.9
1983/84	rate	225/500	155/225		5/337	34/293	0/2065	102/561	46/1260	28/494		7/3792	35/2725
	%	51	69		1.5	12	-	18	3.6	5.7		0.2	1.3
1984/85	rate	285/500			12/285		1/2000	38/201	4/1327	36/813	214/5395	7/3949	57/3019
	%	57			4.2		0.05	19	0.3	4.4	4.0	0.2	1.9
TOTAL	rate	1523/2500	188/360	78/130	17/622	34/293	1/7304	253/1734	235/5378	68/1445	250/8732	30/16688	149/13232
	%	61	52	60	2.7	12	0.01	15	4.3	4.7	2.9	0.2	1.1

* Data supplied by Animal Health Division, Agriculture Canada.

Table 5-5. *Salmonella* isolations from various categories of animal feed.*

Fiscal year	Feeds	Meat, bone meal	Fish meal	Premix supplement	Poultry by-product meal	Hydrolyzed poultry feathers	Blood meal	Cracklings	Environment	TOTAL
1981/82	1	32	5	7	1	1	2	1	1	51
1982/83	3	27	8	14	6	3	-	-	1	62
1983/84	7	44	8	29	11	-	3	-	-	102
1984/85	8	11	15	-	-	1	3	-	-	38
TOTAL	19	114	36	50	18	5	8	1	2	253

* Data supplied by Animal Health Division, Agriculture Canada.

Table 5-6. Salmonella serovars isolated from milk powder plants 1980-1984.*

Serovar	1980	1981	1982	1983	1984	TOTAL
agona	10	4	11	17	8	50
anatum	10	3		1	2	16
california	2					2
cerro	1		3			4
cubana	4					4
derby	1					1
hadar					5	5
heidelberg				1		1
infantis				2		2
johannesburg					1	1
manhattan	3					3
mbandaka				2		2
montevideo		2			2	4
muenchen			1			1
muenster			7	1	1	9
newington			1			1
newport		3	3	3		9
oranienburg			1			1
schwarzengrund				1		1
senftenberg	22	10	7			39
taksony	1	2				3
tennessee	5	10	2	2		19
thomasville				1		1
thompson	3		11	1		15
typhimurium	1	1			2	4
untyped				8	28	36
TOTAL	63	35	47	40	49	234

* Data supplied by Animal Health Division, Agriculture Canada.

5.3 EXAMPLES OF FOOD-BORNE SALMONELLOSIS EPISODES

5.3.1 SALMONELLA ENTERITIDIS TRANSMISSION BY CAKES

Near Leamington, Ontario, during January and February 1978, 264 persons consumed cakes produced by one bakery 2 days previously, and 146 developed diarrhea 1-8 days subsequently (Health and Welfare Canada 1978b). Although S. enteritidis was isolated from the incriminated batch of cakes, the bakery premises, cakes from other days and all other cake ingredients did not yield Salmonella. Feces of 10 asymptomatic bakery workers, including two who were involved in production of the Salmonella-infected cakes, revealed S. enteritidis. These two workers admitted to tasting the cakes during production and to eating the finished product.

5.3.2 SALMONELLA TYPHIMURIUM TRANSMISSION BY DESSERT

At a centre for the mentally retarded in southwest Ontario during September 1984, gastroenteritis affected 249 persons, including nine dietary and counselling staff, seven of whom consumed a Spanish creme dessert at the same time as the residents. Salmonella typhimurium was isolated from 24 fecal samples submitted by residents and staff, and from two dessert samples (Health and Welfare Canada 1985d). The dessert was prepared by addition of raw egg whites to a hot mixture of egg yolks and thickening agent, resulting in an incubation temperature that would have permitted rapid multiplication of Salmonella. Thereafter, the dessert was held unrefrigerated for several hours before serving.

5.3.3 SALMONELLA BERTA TRANSMISSION BY RAW GOAT MILK

During October 1985, S. berta was isolated from feces of an infant who was hospitalized with gastroenteritis in Chilliwack, B.C. (Health and Welfare Canada 1985e). This rare serovar was isolated from the infant's father who had gastroenteritis and also from raw goat milk supplied by a local farmer, and from feces of five members of the family who owned the goat, all of whom were asymptomatic.

5.4 SALMONELLOSIS FROM OTHER ENVIRONMENTAL SOURCES

5.4.1 GASTROENTERITIS AT A DAYCARE

During August 1984, 15 children attending a daycare in suburban Toronto, together with seven staff members, developed gastroenteritis, symptoms of which resolved after 1-2 days (Health and Welfare Canada 1985a). Although S. typhimurium was isolated from feces of one of the children and S. london was recovered from another, six additional children yielded isolates of coxsackievirus B3 and two others revealed Giardia lamblia in stools.

5.4.2 SALMONELLA TYPHIMURIUM TRANSMISSION BY GARTER SNAKE

A girl, aged three years, was hospitalized with diarrhea and vomiting in St. John's, Newfoundland, during February 1985 (Health and Welfare Canada 1985b). Salmonella typhimurium was isolated from feces of this girl and her brother, aged four years, who also had gastroenteritis. Feces from a pet garter snake yielded S. typhimurium.

5.4.3 SALMONELLA POONA TRANSMISSION BY TURTLES

During late December 1984, feces from the father and three of four children in a suburban Vancouver, B.C., family who had gastroenteritis yielded isolates of S. poona (Health and Welfare Canada 1985c). This family frequently visited a relative's home where two pet turtles had been kept during the preceding two months. Water from the tank in which the turtles were kept yielded S. poona.

6.0 COSTS OF SALMONELLOSIS EPISODES

6.1 DIRECT COSTS

Direct costs have been determined for outbreaks of salmonellosis in several Canadian situations: (i) an institution for mentally retarded children where costs of hospitalization and laboratory utilization were readily quantifiable; (ii) a family where costs of professional services by medical and allied health personnel were available; and (iii) a bakery where costs of epidemiological investigations were obvious. Loss of employee wages were significant components in the outbreaks involving the children's institution and the bakery.

6.1.1 *SALMONELLA TYPHIMURIUM* AT AN INSTITUTION FOR MENTALLY RETARDED CHILDREN

In an outbreak involving 249 persons at a regional centre for mentally retarded children in Ontario during September 1984, including 236 patients and 13 staff members, 13 persons were hospitalized with complications and two died, including one of the hospitalized cases (Health and Welfare Canada 1985d). Costs associated with this episode, excluding medication and fees for physicians and allied health personnel, were:

Hospitalization (13 persons for 131 days)	$34 060.00
Laboratory analyses	5 116.00
Investigation, follow-up and legal fees at an inquest	10 775.00
Loss of employee wages (10 persons for 150 days)	11 577.00
TOTAL	$61 528.00

6.1.2 *SALMONELLA INFANTIS* AND *S. JAVA* IN A FAMILY

An outbreak involving five of six members of one family near Quebec City during April 1978 was attributed to consumption of fresh fish prepared at home (Health and Welfare Canada 1978c). Direct costs of investigation and treatment totalled $2392.00 thus:

Epidemiological investigations		
Epidemiologists (18 hours x $26.00)	$468.00	
Nurses, health inspectors (6 visits x $24.00)	144.00	
Fecal cultures (20 cultures x $16.25)	325.00	$937.00

Medical expenses		
Hospitalization (9 days x $120.00)	$1080.00	
Consultations	240.00	
Medications	45.00	$1365.00
Costs to the family		
Visits to the hospital (8 visits x $10.00)	$ 80.00	
Visits to physicians (2 visits x $5.00)	10.00	$ 90.00
TOTAL		$2392.00

Additional surveillance of fresh fish supplies, including bacteriological assays, which was conducted by the Quebec Department of Agriculture during four months following the episode, was estimated to cost $1640.00.

6.1.3 SALMONELLA BAREILLY SPREAD FROM A BAKERY

An outbreak involving 44 persons in southwestern Ontario was attributed to consumption of filled and iced cakes purchased from a local bakery (Health and Welfare Canada 1978c). The cakes contained batter and icing prepared from cracked eggs obtained from a local egg-grading station. Direct costs associated with this episode totalled $23 523.00:

Wages lost	$ 5 463.00
Medical and hospital expenses (4 cases hospitalized for 5.3 days each)	3 287.00
Epidemiological investigations (health units $3703, bacteriological tests $8120)	11 823.00
Income lost by bakery owner	2 950.00
TOTAL	$23 523.00

7.0 SCIENTIFIC CRITERIA

7.1 SALMONELLOSIS ASSOCIATED WITH FOODSTUFFS AND THEIR METHOD OF PREPARATION AND DISTRIBUTION

Scientific criteria emerge from data concerning the seven most commonly occurring Salmonella serovars, each of which was identified as the sole enteric bacterial pathogen in 10 or more episodes of food-associated gastroenteritis in Canada between 1973 and 1982 (Table 5-2).

Salmonella typhimurium was the dominant serovar which induced 127 of 231 (55%) episodes involving 3843 of 7389 (52%) cases. The dominant foodstuff was poultry in 50 of 90 (53%) episodes in which a food vehicle was clearly identified. Food was purveyed or acquired most frequently through a restaurant or bakery in 39 of 124 (31%) episodes. Mishandling of food to permit its infection by Salmonella occurred most frequently at a restaurant or bakery in 34 of 106 (32%) episodes.

Poultry (turkey or chicken) was clearly the dominant food vehicle associated with gastroenteritis episodes induced by five of seven serovars and was implicated in 86 of 173 (50%) episodes where the environmental source was identified. Raw milk was the dominant food vehicle for 9 of 11 episodes (82%) of S. muenster infection, whilst eggs comprised the commonest vehicle in 5 of 22 (23%) episodes due to S. enteritidis. Restaurants and/or bakeries were the commonest purveyors of contaminated foodstuffs in 66 of 222 (30%) episodes involving five of seven serovars, but 7 of 15 (47%) episodes of S. heidelberg gastroenteritis were induced by food purveyed at social functions, and in 6 of 11 (55%) episodes induced by S. muenster the infected milk was purveyed through farms. Restaurants and/or bakeries were the commonest locations where improper procedures for food preparation (i.e. mishandling of foodstuffs) permitted contamination by Salmonella in 55 of 191 (29%) episodes, whilst hospitals were implicated most commonly in 5 of 17 (29%) episodes due to S. infantis and in 6 of 11 (55%) episodes due to S. muenster.

The above criteria apply generally to the 40 Salmonella serovars associated with 321 episodes comprising 10 004 patients in Canada during the decade 1973-1982 (Table 5-1), together with 51 episodes comprising 562 patients due to untyped Salmonella isolates and 32 episodes involving 1655 patients due to multiple Salmonella serovars.

Poultry supplied to food processing establishments exhibited high Salmonella infection rates (61% chickens, 60% geese, 52% turkeys) consistently each year in 1980-1985 (Table 5-4). Thus, poultry comprised an effective vehicle for introduction of Salmonella infection into the human food chain, accounting for 50% bacteriologically confirmed episodes of human infection where the environmental source was identified. High rates in poultry contrasted with low rates for beef

(2.7%) and pork (12%) which were associated with 56 of 404 (14%) episodes due to all serovars.

Animal feed showed consistently elevated annual Salmonella infection rates of 11-19% (average 15%) (Table 5-4), of which meat and bone meal showed highest infection rates of 45%, together with premix supplement 20% and fish meal 14%. These animal feeds probably serve as important vehicles of introduction of Salmonella into poultry which are subsequently processed for human consumption, as in the diagram:

ANIMAL FEEDS	→	POULTRY	→	RESTAURANT	→	HUMAN
meat, bone meal		turkey, chicken		inadequate cooking temp., contamination of non-poultry uncooked foods		salmonellosis

Raw milk acquired from farms was the vehicle of transmission in 9 of 11 (82%) episodes of S. muenster infection, eight of which occurred during 1982 when it was isolated on seven occasions from raw milk supplied to milk powder plants (Table 5-6). Raw milk appeared to be the prime vehicle of infection for humans on that occasion.

Although five Salmonella serovars were isolated from 15 or more samples among 224 samples of raw milk supplied to milk powder plants between 1980 and 1984, none of these was associated with milk-borne infection of humans. These findings indicate the effectiveness of heat treatment during the preparation of milk powder in the elimination of pathogenic Salmonella.

7.2 SALMONELLA ATTACK RATES BY PROVINCE

The reported mean annual attack rate of salmonellosis in the Canadian population between 1978 and 1985 was 34 per 100 000. Regions of lowest prevalence, 17-29 per 100 000, were Quebec and the two adjacent mainland Atlantic provinces of New Brunswick and Nova Scotia, together with Manitoba; regions with intermediate prevalence, 30-37 per 100 000, comprised the three western provinces of Saskatchewan, Alberta and British Columbia; an upper intermediate prevalence of 43 per 100 000 was recorded for Ontario which is the most populous province and located in central Canada; the highest incidences ranging from 55 to 95 per 100 000 were recorded in the most sparsely populated regions of Canada comprising the two island Atlantic provinces of Newfoundland and Prince Edward Island, and the two subarctic-plus-arctic jurisdictions, the Northwest Territories and Yukon Territory.

High Salmonella incidences in the Territories and Newfoundland correlate well with the generally rocky, lightly vegetated shield, taiga or tundra terrain with Ecozones 9-15 (Environment Canada 1986). The sparse human population dwells mainly in tiny communities with less than 100-300 persons each. Organized community sanitary disposal systems are often absent or ineffective, especially during freeze-up and thaw. However, a substantial proportion of the Newfoundland population dwells in the well-sanitated metropolitan area of St. John's.

The apparently high mean annual incidence in Prince Edward Island was skewed, due to a Salmonella contamination in a cheese factory during 1984. This probably contributed to the unusually high rate of reported salmonellosis in the neighbouring Atlantic provinces of Newfoundland and New Brunswick during the same year, where this cheese was marketed extensively. Additional cases arose in Ontario from consumption of contaminated cheese from Prince Edward Island.

8.0 PREAMBLE TO RECOMMENDATIONS

8.1 PROPER HANDLING OF FOODSTUFFS

Kitchen preparation of all raw meats should be separated from all other food preparation tasks, yet this concept is poorly understood.

Knowledge of cooking times for poultry and other meats is not well disseminated.

Cooking times for meats in microwave ovens are not standardized in Canada. Limited data obtained in one U.S.A. study showed absence of staphylococci and coliforms from standard aerobic plate counts of scrambled eggs after 30 seconds of exposure to microwave cooking when temperatures were 35-92°C and roast beef after 60 seconds of microwave cooking at temperatures of 43-93°C (Matthews 1985).

There is inadequate knowledge among voluntary catering groups concerning prevention of food-borne salmonellosis.

8.2 ANTIBIOTIC SENSITIVITIES

Provincial laboratories no longer tabulate and publish annual lists of antimicrobial sensitivities of Salmonella serovars isolated by them. Some provincial laboratories do not conduct antibiotic sensitivity tests on Salmonella isolates.

Antibiotic sensitivities of Salmonella isolates from raw meats and other unprocessed foodstuffs are not routinely performed or published by regulatory agencies.

9.0 RECOMMENDATIONS

9.1 PROPER HANDLING OF FOODSTUFFS

- Repeated nationwide in-service education of kitchen staffs in commercial and institutional food-preparation areas, particularly concerning:

  a) preparation of fresh meat and poultry in areas distinct from other foods;

  b) adequate cooking times for meats;

  c) Canadian standards for inactivation of bacterial food pathogens by microwave cooking.

- Simple but effective practices for volunteer groups who prepare food for social functions to prevent food-borne salmonellosis.

9.2 ANTIBIOTIC SENSITIVITIES

- Annual reporting by provincial laboratories through the Laboratory Centre for Disease Control of antibiotic sensitivities of all Salmonella serovars isolated from humans, foodstuffs and environmental sources during investigation of episodes of food-borne salmonellosis.

- Annual reporting by Agriculture Canada of antibiotic sensitivities of all Salmonella isolates from animal foodstuffs surveyed routinely.

REFERENCES

Association of Official Analytical Chemists. 1984. Salmonella in foods: detection and identification. Official methods of analysis of the Association of Official Analytical Chemists Inc., Arlington, VA. 14th edition. pp. 965-969.

Bergey's Manual of Systematic Bacteriology. 1984. Edited by N.R. Krieg and J.G. Holt. Williams and Wilkins, Baltimore. Vol. 1, p. 247.

Cerqueira-Campos, M-L., Peterkin, P.I. and Sharpe, A.N. 1986. Improved immunological membrane filter method for detection of food-borne Salmonella strains. Appl. Environ. Microbiol. 52: 124-127.

Environment Canada. 1986. State of the Environment Report for Canada.

Health and Welfare Canada. 1978a. Methods for the isolation and identification of Salmonella from foods. MFA 20. Health Protection Branch, Health and Welfare Canada, Ottawa.

Health and Welfare Canada. 1978b. Quarterly Report on Human Salmonellosis in Canada. First Quarter 1978. Can. Dis. Wkly. Rep. 4: 113-116.

Health and Welfare Canada. 1978c. Cost analysis of an outbreak of Salmonellosis: Quebec, Ontario. Can. Dis. Wkly. Rep. 4: 165-167.

Health and Welfare Canada. 1985a. Outbreak of diarrhea at a day nursery - Ontario. Can. Dis. Wkly. Rep. 11: 9-11.

Health and Welfare Canada. 1985b. Salmonella infections from reptiles - Newfoundland. Can. Dis. Wkly. Rep. 11: 117.

Health and Welfare Canada. 1985c. Salmonella poona from pet turtles - British Columbia. Can. Dis. Wkly. Rep. 11: 117-118.

Health and Welfare Canada. 1985d. Salmonella outbreak at a facility for the developmentally handicapped - Ontario. Can. Dis. Wkly. Rep. 11: 182-183.

Health and Welfare Canada. 1985e. Outbreak of an unusual Salmonella serotype spread by goat's milk - British Columbia. Can. Dis. Wkly. Rep. 11: 219-220.

Health and Welfare Canada. 1986. Notifiable Diseases Summary. Can. Dis. Wkly. Rep. 12: 16.

Matthews, M.E. 1985. Microwave ovens: effects on food quality and safety. J. Am. Diet. Assoc. 85: 919-921.

Public Health Laboratory Service. 1986. Top Ten Salmonella Serotypes. 2nd Quarter 1986. Commun. Dis. Rep. 86/28: 4.

PUBLICATIONS

of the
du

NRCC Associate Committee on Scientific Criteria for Environmental Quality
CNRC-Comité associé sur les critères scientifiques concernant l'état de l'environnement

NRCC No.
CNRC n°

12678 Inventory of Pollution-Relevant Research in Canada. Interim Report, Vols. 1, 2.
Etat de recherches sur la pollution au Canada. Rapport provisoire, Tomes 1, 2.
1972. 310 pp. $6.50. (Out of print - Edition épuisée)

14108 Inventory of Pollution-Relevant Research in Canada. Vols. 3, 4.
Etat de recherches sur la pollution au Canada. Tomes 3, 4.
1975. 558 pp. $6.50.

12226 Environmental Fluoride (Special Report). 1971. 39 pp.

12226 Le fluor dans l'environnement. 1971. 41 pp.

13079 Detection and Inactivation of Enteroviruses in Water. 1973. 26 pp. $1.25.

13080 Problems and Selection of Topics for Compilation of Cause/Effect Data. 1973. 51 pp. $1.25.

13236 Détection et inactivation des entérovirus dans l'eau. 1973. 30 pp. $1.25.

13339 Problèmes et choix de thèmes en vue d'une compilation de données cause/effet. 1974. 45 pp. $1.25.

13501 The Effects of Pulp and Paper Wastes on Aquatic Life with Particular Attention to Fish and Bioassay Procedures for Assessment of Harmful Effects. 1973. 60 pp. $2.50.

13502 L'effet des déchets de pâtes et papier sur la vie aquatique. 1974. 75 pp. $2.50.

13566 A Criteria Digest on Radioactivity in the Environment. 1974. 53 pp. $1.50.

13567 Un résumé de critères sur la radioactivité dans l'environnement. 1974. 45 pp. $1.50.

13682 Lead in the Canadian Environment. 1973. 116 pp. $2.00. (Out of print - See NRCC 16736).

13683 Le plomb dans l'environnement canadien. 1973. 130 pp. $2.00. (Edition épuisée - voir CNRC 16737).

13684 Picloram: The Effects of Its Use as a Herbicide on Environmental Quality. 1974. 128 pp. $5.00.

13685 Piclorame: les effets de son utilisation comme herbicide sur l'état de l'environnement. 1974. 130 pp. $1.00.

13686 A Method of Monitoring Nationally for Possible Delayed Effects of Various Occupational Environments. 1974. 42 pp. $1.25.

13687 Une méthode de surveillance nationale des effets possibles, à long terme, du milieu professionnel sur la santé. 1974. 40 pp. $1.25.

13688 Environmental Cause/Effect Phenomena Relating to Technological Development in the Canadian Arctic. 1974. 125 pp. $2.00.

13689 Phénomènes environnementaux de cause à effet liés au progrès technique dans l'arctique. 1974. 128 pp. $2.00.

13690 The Application of the Phosphorus Loading Concept to Eutrophication Research. 1974. 42 pp. $1.25.

13691 Application du concept de la vitesse d'apport de phosphore par unité de surface à la recherche sur l'eutrophisation. 1974. 44 pp. $1.25.

Available through prepaid purchase orders from

En vente, moyennant commandes prepayées, au Service des

Publications, NRCC/CNRC
Ottawa, Ontario K1A 0R6

NRCC No.
CNRC n°

14094 Chlordane: Its Effects on Canadian Ecosystems and Its Chemistry. 1974. 189 pp. $1.00.

14095 Chlordane: ses effets sur les écosystèmes canadiens et sa chimie. 1975. 192 pp. $1.00.

14096 Photochemical Air Pollution: Formation, Transport and Effects. 1975. 224 pp. $2.50 (out of print).

14097 La pollution photochimique de l'air: sa formation, son transport et ses effets. 1976. 203 pp. $2.50.

14098 Endosulfan: Its Effects on Environmental Quality. 1975. 100 pp. $1.25.

14099 Endosulfan: ses effets sur l'état de l'environnement. 1976. 98 pp. $1.25.

14100 Waterborne Dissolved Oxygen Requirements and Criteria With Particular Emphasis on the Canadian Environment. 1975. 111 pp. $2.00.

14101 Exigences et critères relatifs à l'oxygène dissous dans l'eau, et leurs particularités à l'environnement canadien. 1976. 111 pp. $2.00.

14102 Methoxychlor: Its Effects on Environmental Quality. 1975. 164 pp. $2.00.

14103 Méthoxychlore: ses effets sur l'état de l'environnement. 1976. 161 pp. $2.00.

14104 Fenitrothion: The Effects of Its Use on Environmental Quality and Its Chemistry. 1975. 162 pp. $2.00.

14105 Fénitrothion: effets de son utilisation sur l'état de l'environnement, et sa chimie. 1976. 164 pp. $2.00.

14106 Arboviruses and Human Health in Canada. 1975. 35 pp. $1.25.

14107 Arbovirus pathogènes au Canada. 1976. 40 pp. $1.25.

14109 Waste Heat in the Aquatic Environment. 1975. 40 pp. $1.00.

14110 Pollution thermique de l'environnement aquatique. 1976. 68 pp. $1.00.

15015 Sulphur and Its Inorganic Derivatives in the Canadian Environment. 1977. 426 pp. $5.00.

15016 Le soufre et ses dérivés minéraux dans l'environnement canadien. 1978. 441 pp. $5.00.

15017 Effects of Chromium in the Canadian Environment. 1976. 168 pp. $2.00.

15018 Les effets du chrome dans l'environnement canadien. 1977. 162 pp. $2.00.

15019 The Effects of Alkali Halides in the Canadian Environment. 1977. 171 pp. $2.00.

15020 Les effets des halogénures alcalins dans l'environnement canadien. 1977. 171 pp. $2.00.

15021 The Effects of Petroleum Refinery Liquid Wastes on Aquatic Life, with Special Emphasis on the Canadian Environment. 1976. 77 pp. $2.00.

15022 Les effets des déchets liquides du raffinage du pétrole sur la vie aquatique, particulièrement dans l'environnement canadien. 1977. 86 pp. $2.00.

15023 NTA (Nitrilotriacetic Acid) - An Ecological Appraisal. 1976. 46 pp. $1.25.

15024 NTA (acide nitrilotriacétique) - une analyse écologique. 1977. 48 pp. $1.25.

15383 Effects of Noise on Man. 1976. 87 pp. $2.50.

15384 Les effets du bruit sur l'homme. 1977. 92 pp. $2.50.

15385 Bacillus thuringiensis: Its Effects on Environmental Quality. 1976. 133 pp. $2.00.

15386 Bacillus thuringiensis: ses effets sur l'état de l'environnement. 1977. 127 pp. $2.00.

15387 Medicare Data: Its Use in Defining the Effects of the Environment on Health. 1977. 164 pp. $2.50.

15388 Les statistiques de l'assurance-maladie et leur rôle dans la définition de l'influence de l'environnement sur la santé. 1978. 166 pp. $2.50.

NRCC No.
CNRC n°

15389 Fenitrothion: The Long Term Effects of Its Use in Forest Ecosystems - Current Status. 1977. 18 pp. $1.00.

15391 Effects of Arsenic in the Canadian Environment. 1978. 363 pp. $2.00.

15392 Les effets de l'arsenic sur l'environnement canadien. 1979. 415 pp. $2.00.

16073 Proceedings of a Symposium on Fenitrothion: The Long-Term Effects of Its Use in Forest Ecosystems. Comptes rendus du symposium sur le fénitrothion: les effets à long terme de son utilisation dans les écosystèmes forestiers. 1977. 628 pp. $10.00.

16074 Fénitrothion: effets à long terme de son utilisation dans les écosystèmes forestiers - situation actuelle. 1977. 20 pp. $1.00.

16075 Phenoxy Herbicides: Their Effects on Environmental Quality with Accompanying Scientific Criteria for 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD). 1978. 440 pp. $10.00.

16076 Herbicides phénoxy - analyse de leurs effets sur l'état de l'environnement accompagnée de critères scientifiques à l'égard de la 2,3,7,8-tétrachlorodibenzo-p-dioxine (TCDD). 1979. 452 pp. $2.00.

16077 Polychlorinated Biphenyls: Biological Criteria for an Assessment of Their Effects on Environmental Quality. 1978. 172 pp. $2.00.

16078 Polychlorobiphényles: critères biologiques pour évaluer leurs effets sur l'état de l'environnement. 1979. 208 pp. $2.00.

16079 Ecotoxicology of Chlorpyrifos. 1978. 314 pp. $2.00.

16080 Ecotoxicologie du chlorpyrifos. 1979. 250 pp. $2.00.

16081 Environmental Fluoride 1977. 1978. 152 pp. $5.00.

16082 Le fluorure dans l'environnement, 1977. 1979. 175 pp. $2.00.

16446 Effects of Ultraviolet Radiation on Man. 1978. 90 pp. $2.00.

16447 Les effets du rayonnement ultraviolet sur l'homme. 1979. 91 pp. $2.00.

16448 The Biological Effects of Radio-frequency and Microwave Radiation. 1979. 244 pp. $5.00.

16449 Effets biologiques des radiofréquences et des micro-ondes. 1980. 244 pp. $5.00.

16450 The Aqueous Chlorination of Organic Compounds: Chemical Reactivity and Effects on Environmental Quality. 1978. 136 pp. $5.00.

16451 Chloration en milieu aqueux de composés organiques: réactivité chimique et effets sur l'état de l'environnement. 1979. 149 pp. $2.00.

16452 Effects of Asbestos in the Canadian Environment. 1979. 185 pp. $3.00.

16453 Les effets de l'amiante dans l'environnement au Canada. 1980. 202 pp. $3.00.

16454 Copper in the Aquatic Environment: Chemistry, Distribution, and Toxicology. 1979. 227 pp. $3.00.

16455 Le cuivre dans l'environnement aquatique: chimie, répartition et toxicologie. 1980. 249 pp. $3.00.

16736 Effects of Lead in the Environment - 1978. Quantitative Aspects. 1979. 779 pp. $10.00.

16737 Effets du plomb dans l'environnement - 1978. Aspects quantitatifs. 1980. 853 pp. $5.00.

16738 Report of a Special Conference on Hearing Threshold Levels of "Isolated" Human Populations. Comptes rendus du symposium spécial sur les niveaux d'audition des populations humaines "isolées". 1978. 104 pp. $3.00.

16739 Effects of Mercury in the Canadian Environment. 1979. 290 pp. $3.00.

16740 Carbofuran: Criteria for Interpreting the Effects of Its Use on Environmental Quality. 1979. 191 pp. $2.00.

16741 Carbofurane: critères pour interpréter les effets de son utilisation sur l'état de l'environnement. 1980. 184 pp. $2.00.

NRCC No.
CNRC n°

16742 Effets du mercure dans l'environnement au Canada. 1980. 292 pp. $3.00.

16743 Effects of Cadmium in the Canadian Environment. 1979. 148 pp. $5.00.

16744 Les effets du cadmium dans l'environnement canadien. 1979. 150 pp. $3.00.

16745 Effects of Lead in the Canadian Environment - 1978. Executive Report.
Effets du plomb dans l'environnement canadien - 1978. Rapport administratif.
1979. 24 pp. $1.00.

17581 Water Hardness, Human Health, and the Importance of Magnesium. 1979. 119 pp. $3.00.

17582 Dureté de l'eau, santé et importance du magnésium. 1980. 123 pp. $3.00.

17583 Phthalate Esters in the Aquatic Environment. 1980. 108 pp. $3.00.

17584 Esters phtaliques dans l'environnement aquatique. 1981. 110 pp. $3.00.

17585 Executive Reports: Effects of Chromium, Alkali Halides, Arsenic, Asbestos, Mercury, and Cadmium in the Canadian Environment. 80 pp.
Rapports Administratifs: effets du chrome, des halogénures alcalins, de l'arsenic, de l'amiante, du mercure, et du cadmium sur l'environnement canadien. 92 pp.
1980. $3.00.

17586 A Case Study of a Spill of Industrial Chemicals - Polychlorinated Biphenyls and Chlorinated Benzenes. 1980. $5.00.

17587 Effects of Yellow Phosphorus in the Canadian Environment. 1981. 110 pp. $3.00.

17588 Effets du phosphore blanc sur l'environnement canadien. 1981. 112 pp. $3.00.

17589 Zinc in the Aquatic Environment: Chemistry, Distribution, and Toxicology. 1981. 145 pp. $3.00.

17590 Le zinc dans l'environnement aquatique: chimie, répartition et toxicologie. 1981. 152 pp. $3.00.

18128 Intestinal Parasites of Man in the Canadian Environment. 1980. 69 pp. $2.00.

18129 Les parasites intestinaux de l'homme dans l'environnement canadien. 1980. 70 pp. $2.00.

18130 The Ecological Consequences of Dredging and Dredge Spoil Disposal in Canadian Waters.
1982. 142 pp. $5.00.

18131 Les conséquences écologiques du dragage et de l'élimination des résidus du dragage dans les eaux canadiennes. 1983. 150 pp. $5.00.

18132 Effects of Vanadium in the Canadian Environment. 1980. 94 pp. $2.00.

18133 Effets du vanadium dans l'environnement canadien. 1981. 92 pp. $2.00.

18134 Radioactivity in the Canadian Environment. 1980. 129 pp. $3.00.

18135 La radioactivité dans l'environnement canadien. 1981. 133 pp. $3.00.

18156 The Report of the ad hoc Panel Convened by the National Research Council of Canada to Review the Spill of Polychlorinated Biphenyls at the Federal Pioneer Ltd. Site in Regina, Saskatchewan.
30 January 1980. 15 pp.

18467 Hydrogen Sulfide in the Atmospheric Environment: Scientific Criteria for Assessing its Effects on Environmental Quality. 1981. 196 pp. $5.00.

18468 Sulfure d'hydrogène dans l'environnement atmospherique: critères scientifiques pour évaluer ses effets sur la qualité de l'environnement. 1982. 204 pp. $5.00.

18469 Ethylenethiourea: Criteria for the Assessment of its Effects on Man. 1980. 149 pp. $3.00.

18470 Ethylène-thiourée: critères pour évaluer ses effets sur l'homme. 1981. 187 pp. $3.00.

18471 Pesticide-Pollinator Interactions. 1981. 190 pp. $5.00.

18472 Interactions entre pesticides et pollinisateurs. 1981. 223 pp. $5.00.

NRCC No.
CNRC n°

18473 Effects of Aerosols on Atmospheric Processes. 1982. 208 pp. $8.00.

18474 Effets des aérosols sur les processus atmosphériques. 1983. 230 pp. $8.00.

18475 Acidification in the Canadian Aquatic Environment: Scientific Criteria for Assessing the Effects of Acidic Deposition on Aquatic Ecosystems. 1981. 369 pp. $10.00.

18476 Acidification dans l'environnement aquatique au Canada: critères scientifiques pour évaluer les effets du dépôt acide sur les écosystèmes aquatiques. 1982. 377 pp. $10.00.

18564 Effects of Inhaled Particles on Human Health: Influence of Particle Size and Shape. 1982. 177 pp. $8.00.

18565 Effets sur la santé des particules absorbées par voie respiratoire: influence de leur taille et de leur forme. 1983. 195 pp. $8.00

18566 Thermal Effects Upon Fishes. 1982. 200 pp. $8.00.

18567 Effets de la pollution thermique sur les poissons. 1983. 210 pp. $8.00.

18568 Effects of Nickel in the Canadian Environment. 1981. 352 pp. $4.00.

18569 Effets du nickel sur l'environnement canadien. 1982. 347 pp. $4.00.

18570 A Screen for the Relative Persistence of Lipophilic Organic Chemicals in Aquatic Ecosystems - An Analysis of the Role of a Simple Computer Model in Screening.
I. A Simple Computer Model as a Screen for Persistence.
II. An Introduction to Process Analyses and Their Use in Preliminary Screens of Chemical Persistence.
1981. 302 pp. $8.00.

18571 Contrôle de la persistance relative de produits organiques lipophiles dans les écosystèmes aquatiques - analyse du rôle d'une simple simulation par ordinateur. 1982. 335 pp. $8.00.

18572 Effects of Propoxur on Environmental Quality with Particular Reference to its Use for Control of Biting Flies. 1982. 238 pp. $8.00.

18573 Les effets du propoxur sur la qualité de l'environnement, notamment quant à son emploi dans la lutte contre les insectes piqueurs. 1982. 253 pp. $8.00.

18574 Polychlorinated Dibenzo-p-Dioxins: Criteria for Their Effects on Man and his Environment. 1981. 251 pp. $8.00.

18575 Polychlorodibenzo-p-dioxines: critères relatifs à leurs effets sur l'homme et son environnement. 1982. 276 pp. $8.00.

18576 Polychlorinated Dibenzo-p-Dioxins: Limitations to the Current Analytical Techniques. 1981. 184 pp. $8.00.

18577 Polychlorodibenzo-p-dioxines: limites des méthodes analytiques actuelles. 1982. 186 pp. $8.00.

18578 Chlorinated Phenols: Criteria for Environmental Quality. 1982. 191 pp. $8.00.

18579 Chlorophénols: critères pour évaluer leurs effets sur l'état de l'environnement. 1982. 217 pp. $8.00.

18976 Farm Animal Manures in the Canadian Environment. 1983. 139 pp. $8.00

18977 L'effet du fumier dans l'environnement canadien. 1983. 145 pp. $8.00

18978 Workshop on the Combined Effects of Xenobiotics.
Atelier sur les effets combinés des xenobiotiques.
1982. 253 pp. $8.00.

18979 Aminocarb: The Effects of its Use on the Forest and the Human Environment. 1982. 253 pp. $8.00.

18979B Commentaires du groupe d'experts sur Aminocarbe: Effets de son utilisation sur la forêt et l'environnement de l'homme. 1982. 27 pp. $1.00.

18980 Aminocarbe: effets de son utilisation sur la forêt et l'environnement. 1983. 271 pp. $8.00

NRCC No.
CNRC n°

18981 Polycyclic Aromatic Hydrocarbons in the Aquatic Environment: Formation, Sources, Fate and Effects on Aquatic Biota. 1983. 209 pp. $8.00

18982 Les hydrocarbures aromatiques polycycliques dans le milieu aquatique: formation, sources, devenir et effets sur le biote aquatique. 1984. 218 pp. $8.00

18983 The Need for New Directions in Toxicological Funding.
Le besoin d'une nouvelle politique en ce qui concerne les subventions dans le domaine toxicologique.
1982. 11 pp. $2.00.

19244 Ultrasound: Characteristics and Biological Action. 1981. 284 pp. $8.00.

19245 Les ultrasons: caractéristiques et action biologique. 1982. 284 pp. $8.00.

19246 The Effects of Cyanides on Aquatic Organisms with Emphasis upon Freshwater Fishes. 1982.
139 pp. $5.00.

19247 Effets des cyanures sur les organismes aquatiques, notamment sur les poissons d'eau douce.
1983. 144 pp. $5.00.

19248 Biting Flies in Canada: Health Effects and Economic Consequences. 1982. 157 pp. $5.00.

19249 Insectes piqueurs au Canada: effets sur la santé et conséquences économiques. 1983. 169 pp.
$5.00.

19250 Radioactivity in the Canadian Aquatic Environment. 1983. 292 pp. $8.00

19251 La radioactivité dans l'environnement aquatique au Canada. 1983. 292 pp. $8.00

19252 Data Sheets on Selected Toxic Elements. 1982. 61 pp. $5.00.

19253 Fiches de données sur certains éléments toxiques. 1983. 48 pp. $5.00

20640 Cold: Special Aspects in the Canadian North. 1983. 33 pp. $3.00.

20641 Aspects particuliers du froid dans le nord canadien. 1983. 33 pp. $3.00

20642 Proceedings of a Symposium on Monitoring and Assessment of Airborne Pollutants with Special Emphasis on Long-range Transport and Deposition of Acidic Materials and Workshop on Air and Precipitation Monitoring Networks.
Comptes rendus du symposium sur la surveillance et l'évaluation des polluants en suspension dans l'air et notamment sur le transport à grande distance et le dépôt de substances acides et Atelier sur les réseaux de surveillance de l'air et des précipitations.
1983. 502 pp. $8.00.

20643 Interactions of Selenium. 1983. 85 pp. $5.00

20644 Interactions du sélénium avec d'autres éléments. 1983. 85 pp. $5.00

20645 Impact Assessments in Lotic Environments - Methoxychlor. 1983. 130 pp. $5.00

20646 Evaluation des effets du méthoxychlore dans les milieux lotiques. 1984. 144 pp. $5.00

20647 2,4-D: Some Current Issues. 1983. 99 pp. $5.00

20648 2,4-D: quelques questions actuelles. 1984. 106 pp. $5.00

20649 Report on Toxicology in Canada - March 1985. 1985. 40 pp.

22488 TFM and Bayer 73: Lampricides in the Aquatic Environment. 1985. 184 pp. $5.00.

22490 Environmental Aspects of Escherichia coli in Human Health. 1984. 76 pp. $5.00.

22491 Escherichia coli et la santé humaine - aspects environnementaux. 1985. 71 pp. $5.00.

22492 Post "IBT" Assessment of Critical Laboratory Studies on the Mammalian and Avian Toxicology of Fenitrothion. 1984. 110 pp. $5.00

22493 Évaluation des principles études de laboratoire sur la toxicité du fénitrothion pour les mammifères et les oiseaux réalisée à la suite de "l'affaire IBT". 1984. 114 pp. $5.00

22494 Organotin Compounds in the Aquatic Environment: Scientific Criteria for Assessing Their Effects on Environmental Quality. 1985. 284 pp. $10.00

NRCC No.
CNRC n°

22496 Ethylene in the Environment: Scientific Criteria for Assessing its Effect on Environmental Quality. 1985. 183 pp. $8.00

22844 Exposure of the Hand to Vibration in Industry. 1984. 63 pp. $5.00

22845 Exposition de la main aux vibrations dans le secteur industriel. 1985. 65 pp. $5.00.

22846 Polychlorinated Dibenzofurans: Criteria for Their Effects on Humans and the Environment. 1984. 243 pp. $8.00

22848 Mycotoxins: A Canadian Perspective. 1985. 185 pp. $8.00

22852 Epidemiologic Evidence of the Effects of Pesticides on Human Health in Canada. Monograph II. In Strengths and Limitations of Benefit-Cost Analyses Applied to the Assessment of Industrial Organic Chemicals Including Pesticides. 1985. $8.00.

23909 Extrapolation of Toxicological Data from Laboratory Studies to the Human Situation. Monograph III. In Strengths and Limitations of Benefit-Cost Analyses Applied to the Assessment of Industrial Organic Chemicals Including Pesticides. 1985. $8.00.

23917 Chromium Update 1984: Environmental and Nutritional Effects of Chromium. 1985. 56 pp. $5.00

23918 Le Chrome - Mise à jour 1984. Effets environnementaux et nutritionnels du chrome. 1985. 62 pp. $5.00.

23988 Evaluation of the Biological and Economic Benefits of Pesticide Use. Monograph V. In Strengths and Limitations of Benefit-Cost Analyses Applied to the Assessment of Industrial Organic Chemicals Including Pesticides. 1985. 293 pp. $8.00.

23990 A Critical Examination of Environmental Modelling - Modelling the Environmental Fate of Chlorobenzenes Using the Persistence and Fugacity Models. 1985. 206 pp. $8.00.

24371 The Role of Biochemical Indicators in the Assessment of Aquatic Ecosystem Health--Their Development and Validation. 1985. 119 pp. $8.00.

24376 Pyrethroids: Their Effects on Aquatic and Terrestrial Ecosystems. 1986. 303 pp. $8.00.

24438 Rapport sur la toxicologie au Canada - Mars 1985. 1985. 49 pp.

* 24464 Framework for the Application of Benefit-Cost Analyses to the Assessment of Industrial Organic Chemicals. Monograph I. In Strengths and Limitations of Benefit-Cost Analyses Applied to the Assessment of Industrial Organic Chemicals Including Pesticides. $8.00.

* 24465 Quantitative Estimation of the Risk to Humans Resulting from Exposure to Chemicals. Monograph VI. In Strengths and Limitations of Benefit-Cost Analyses Applied to the Assessment of Industrial Organic Chemicals Including Pesticides. $8.00.

24489 Evaluation of Costs Associated with Human Health Impacts. Monograph IV. In Strengths and Limitations of Benefit-Cost Analyses Applied to the Assessment of Industrial Organic Chemicals Including Pesticides. 1985. 161 pp. $8.00.

24759 Aluminum in the Canadian Environment. 1986. 331 pp. $8.00.

24875 Video Display Terminals - Do They Emit Dangerous Levels of Radiation? 1987. 16 pp. $5.00.

* Not yet in print.

Available through prepaid purchase orders from

En vente, voyemmant commandes prepayées, au Service des

Publications, NRCC/CNRC
Ottawa, Ontario K1A 0R6